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Modeling Sea-Level Rise Effects on Population using Global Elevation and Land-Cover Data

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Center of Excellence

CEGIS

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Outline

- Motivation
- Objectives
- History and Potential of Sea Level Rise
- Storm Surge and Effects
- Approach
  - Data Sources
  - Projection Methods and Problems
  - Animation Procedures
- Results
- Conclusions

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Motivation

- Interest in global climate effects
- Availability of high resolution global datasets
- Development of animation capabilities
- Effects of recent catastrophic events with high rises and surges of sea water
  - Hurricanes Katrina and Rita
  - Indian Ocean Tsunami

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Objectives

- Examine effects of sea level rise from global perspective
- Determine effects on global population numbers
- Determine effects in localized areas
- Model with animation of sea level rise

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History and Potential of Global Sea level Rise

- Global sea level and Earth's climate are intricately linked
- Earth climate has warmed about 1º during the last 100 years
- Sea level is rising at 1 to 2 mm per year
- Most of current global land ice mass is in the Antarctic and Greenland ice sheets

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History and Potential of Global Sea level Rise

- **Melting of Antarctic and Greenland ice sheets would cause sea level rise of 80 m**
- **Geological record shows 20 m rise in 500 year period resulting from collapse of Earth's former ice sheets**

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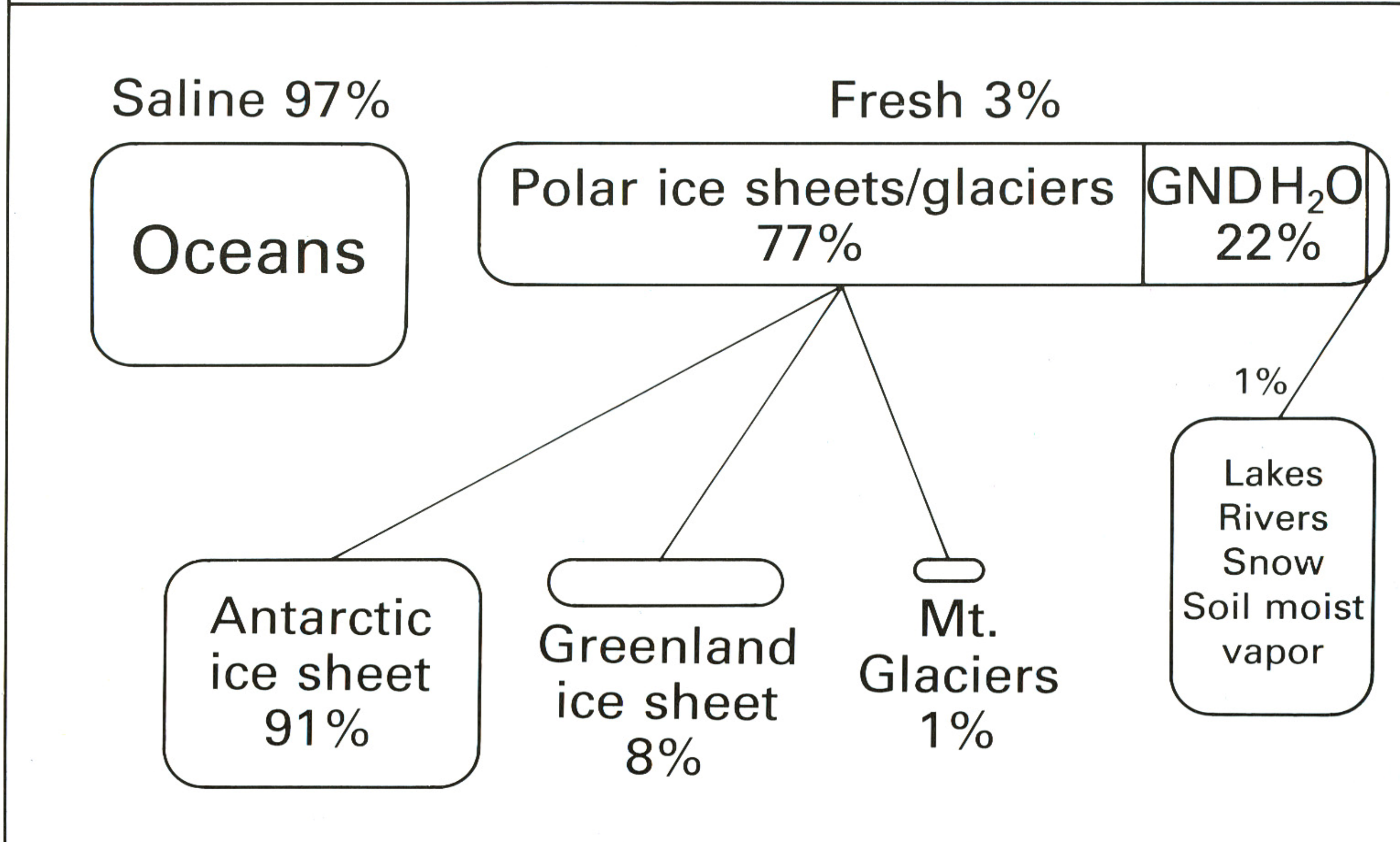
DISTRIBUTION OF EARTH'S WATER



Source: Thomas, 1993

Maximum Potential Sea-Level Rise

Location	Volume	Potential Sea-Level Rise (m)
East Antarctic Ice Sheet	26,039,200	64.80
West Antarctic Ice Sheet	3,262,000	8.06
Antarctic peninsula	227,100	0.46
Greenland	2,620,000	6.55
Other ice caps, fields, glaciers	180,000	0.45
Total	32,328,300	80.32

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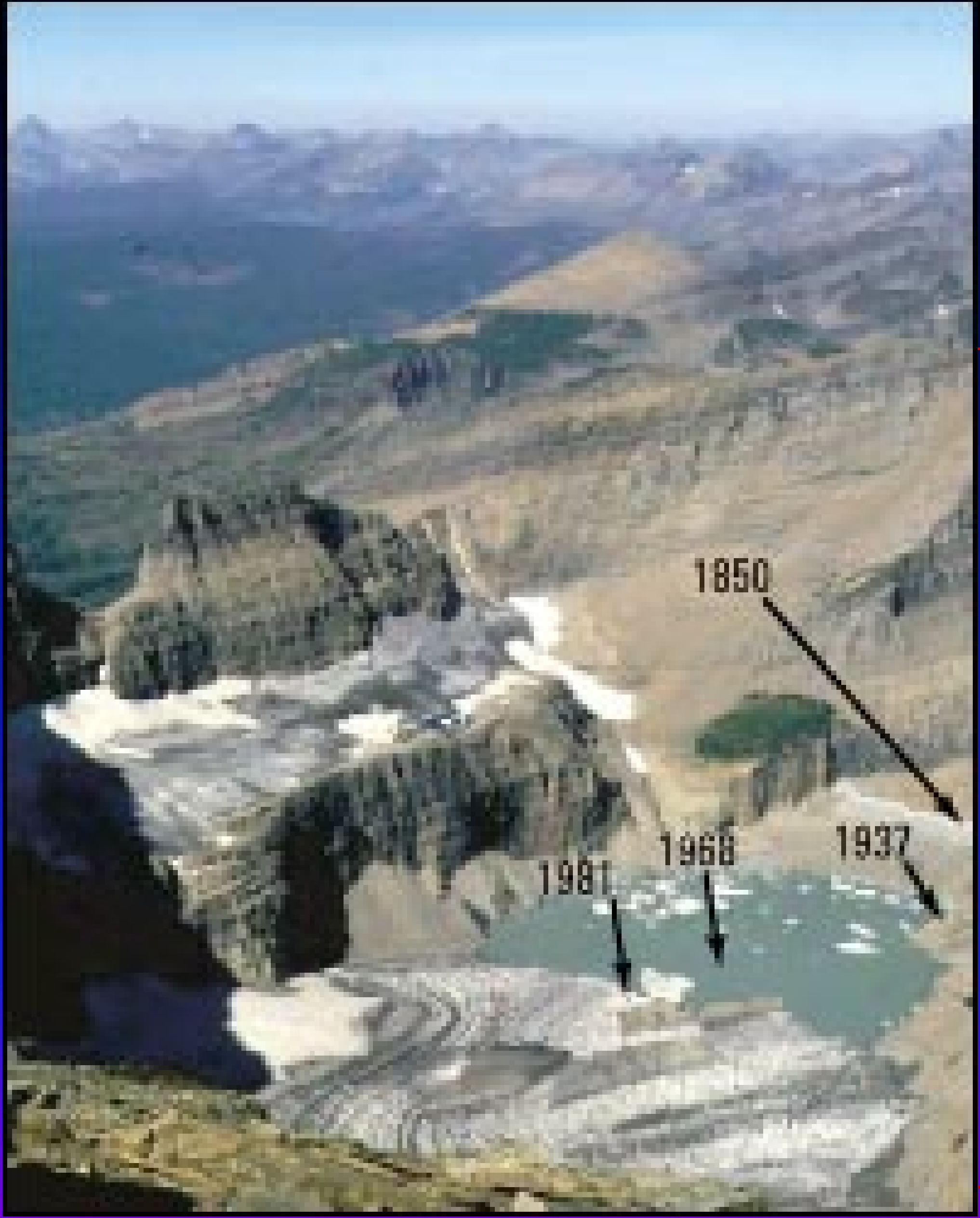
Source: Poore, Williams, and Tracey, 2007



Grinnell Glacier in Glacier National Park, Montana; photograph by Carl H. Key, USGS, in 1981. The glacier has been retreating rapidly since the early 1900's. The arrows point to the former extent of the glacier in 1850, 1937, and 1968. Mountain glaciers are excellent monitors of climate change; the worldwide shrinkage of mountain glaciers is thought to be caused by a combination of a temperature increase from the Little Ice Age, which ended in the latter half of the 19th century, and increased greenhouse-gas emissions.

Source: Poore, Williams and Tracey, 2007

http://www.glaciers.er.usgs.gov/index.htm

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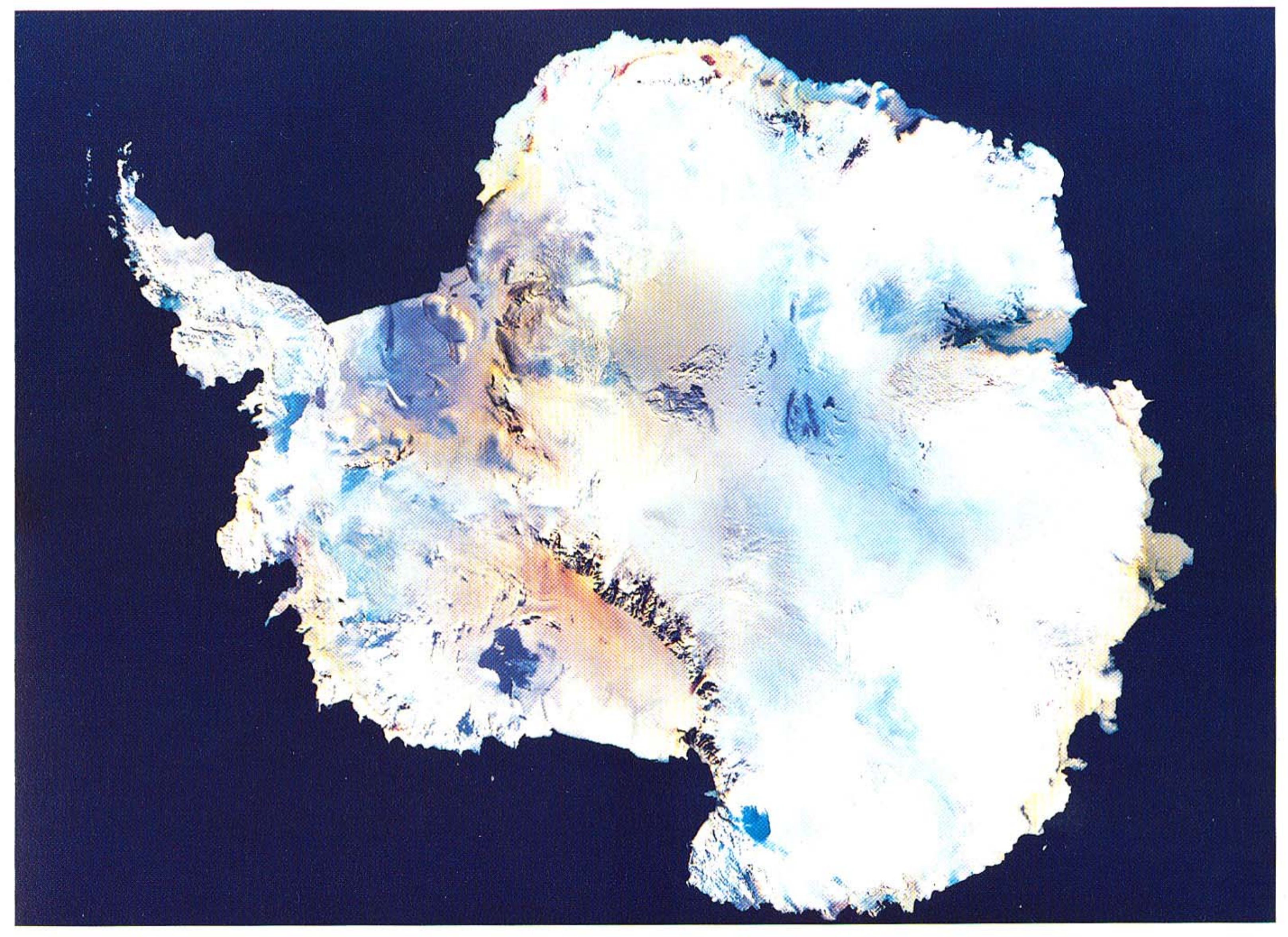
AVHRR Image Mosaic of Antarctica



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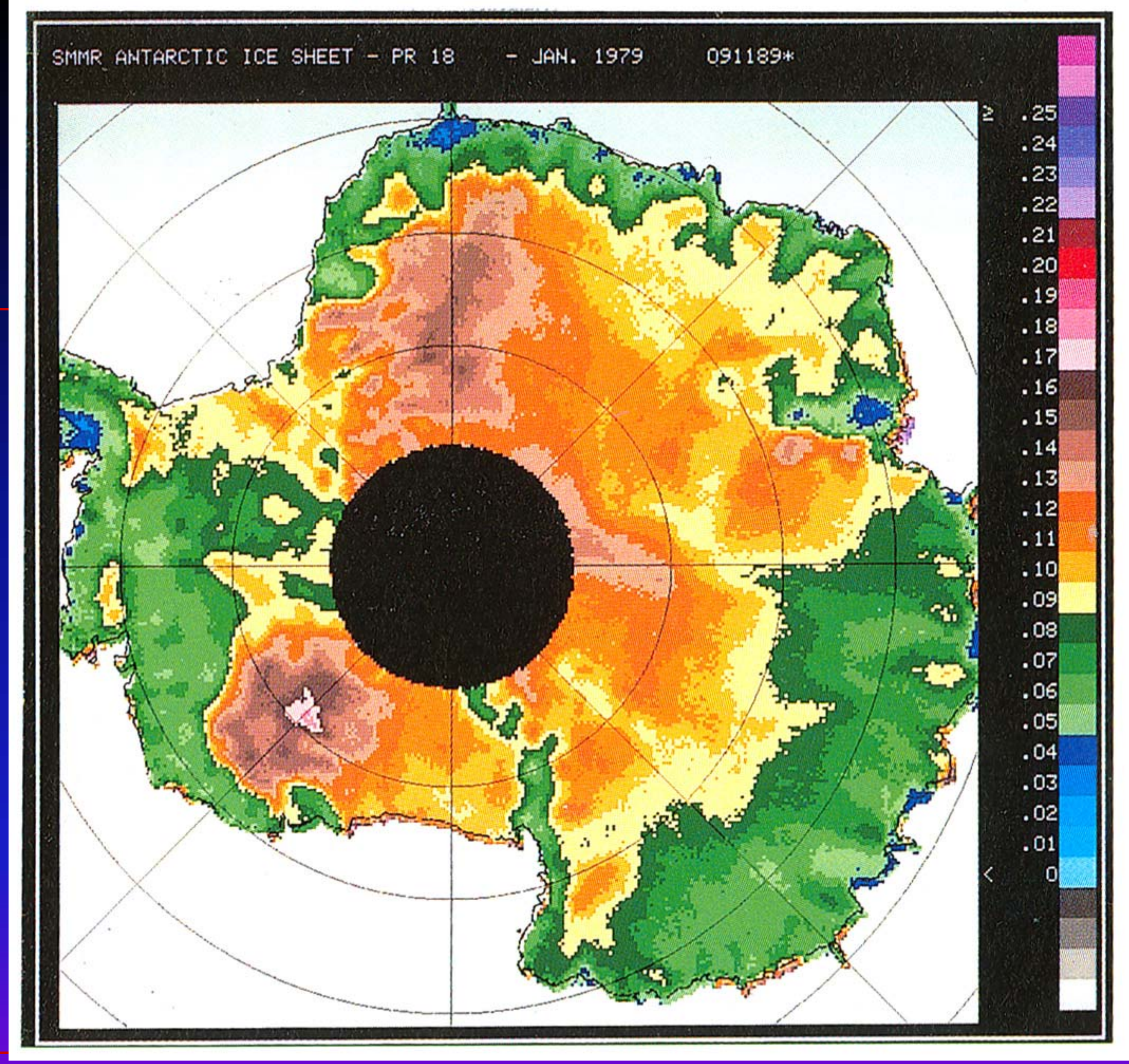
Source: Thomas, 1993

Surface melting from passive microwave measurements.

Blue areas most likely to incur summer melting



Source: Thomas, 1993

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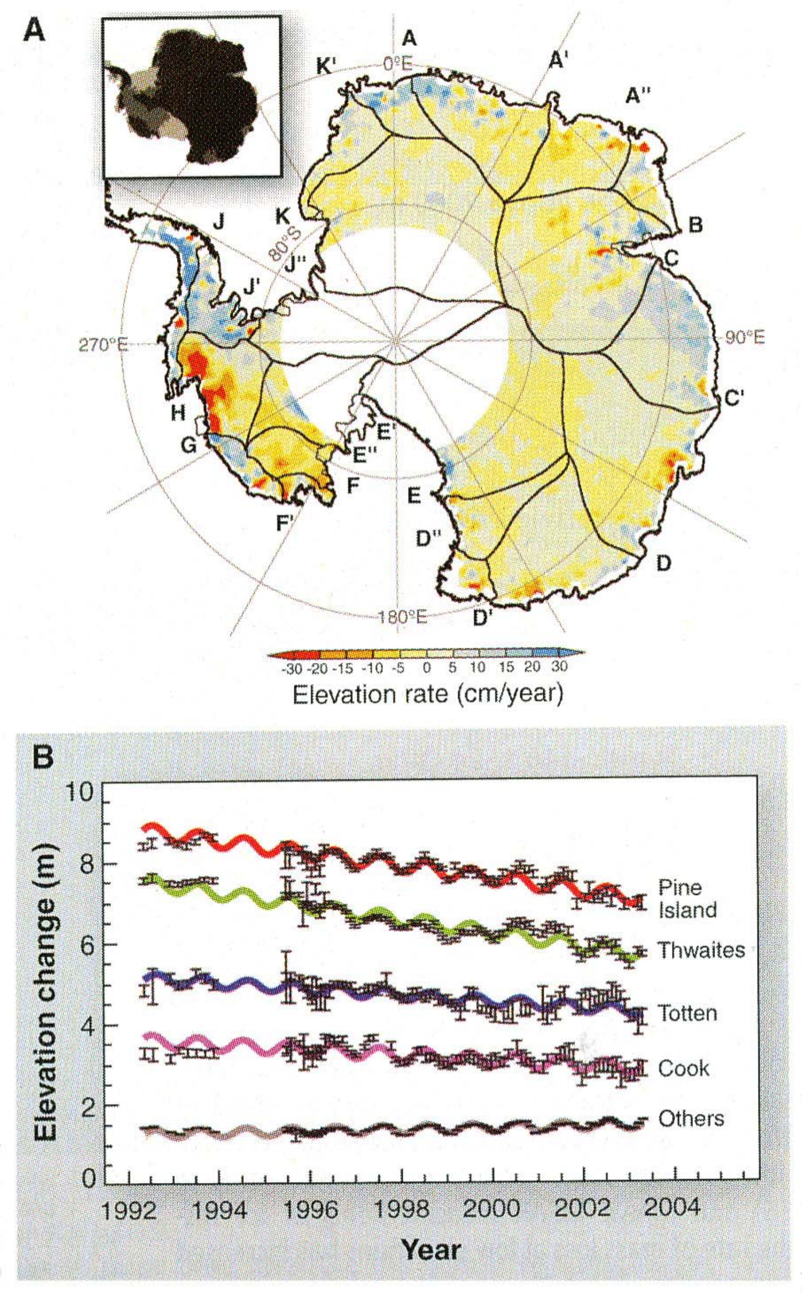
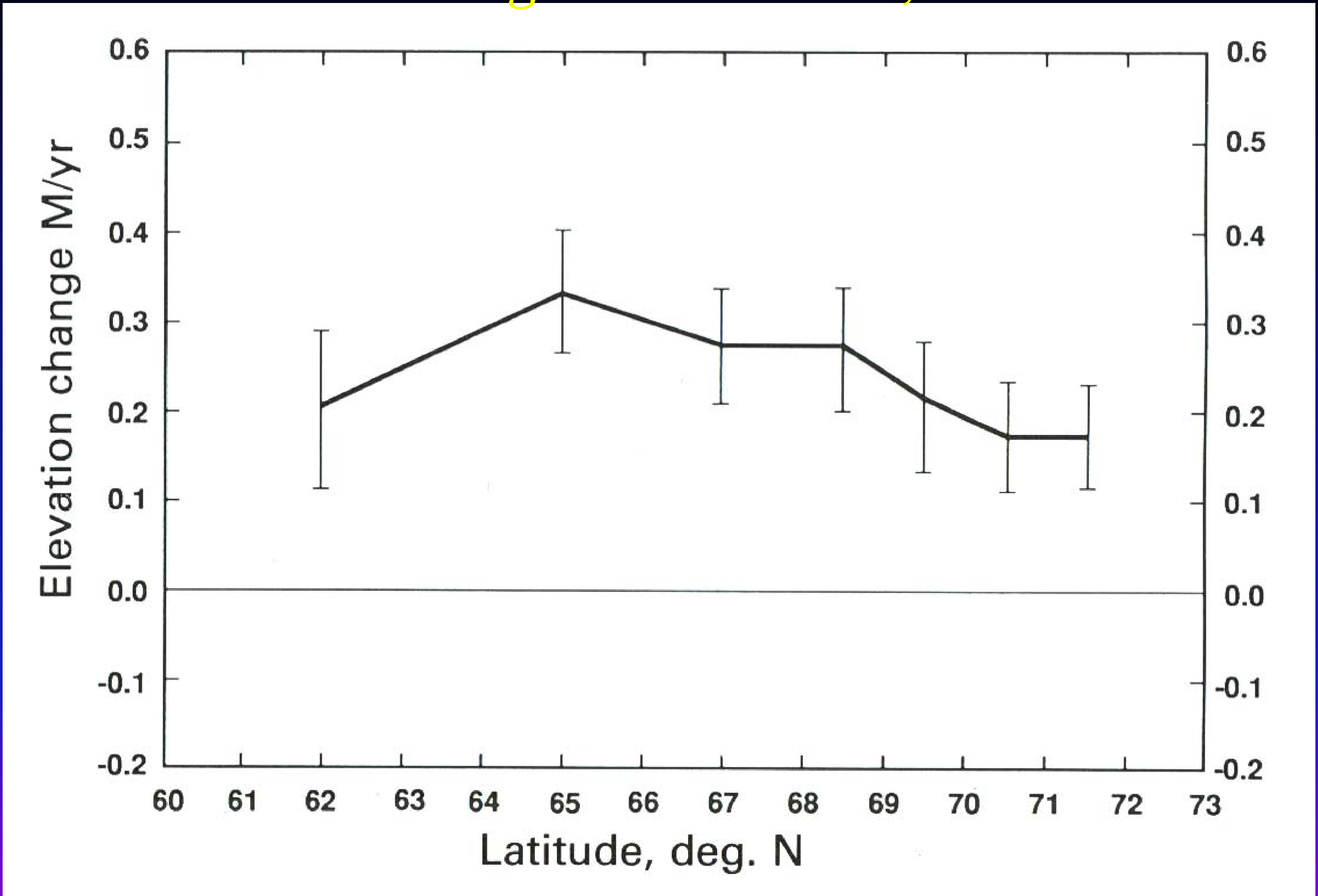
Elevation change on Antarctica

(from ERS satellite altimetry)



Source: Shepherd and Wingham, 2007 (Used with permission)

Elevation Change on Greenland, 1992-2003



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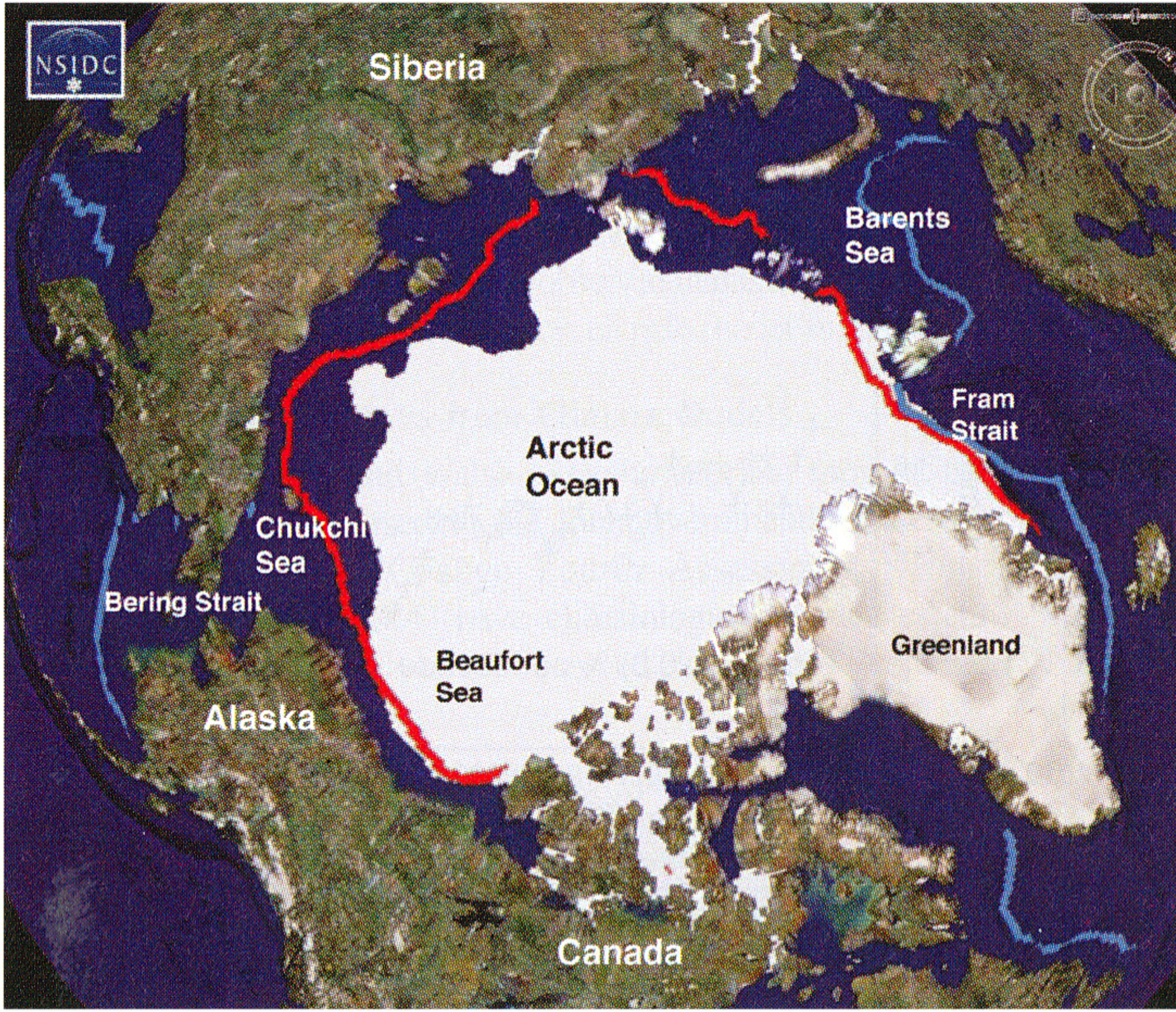
Source: Williams and Hall, 1993

Arctic Sea Ice Extent

September 2005



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Source: Serreze and others, 2007

(Used with permission)

Hurricane Katrina Storm Surge and Effects

Hurricane Katrina Storm Surge

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New Orleans MODIS Images

After and before Katrina

August 30, 2005

August 27, 2005

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Hurricane Katrina Damage Assessments
U.S. Geological Survey Rocky Mountain Geographic Science Center
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Hurricane Rita Storm Surge Effects

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Peveto Beach

Before and after Rita -- Note destruction of houses from storm surge

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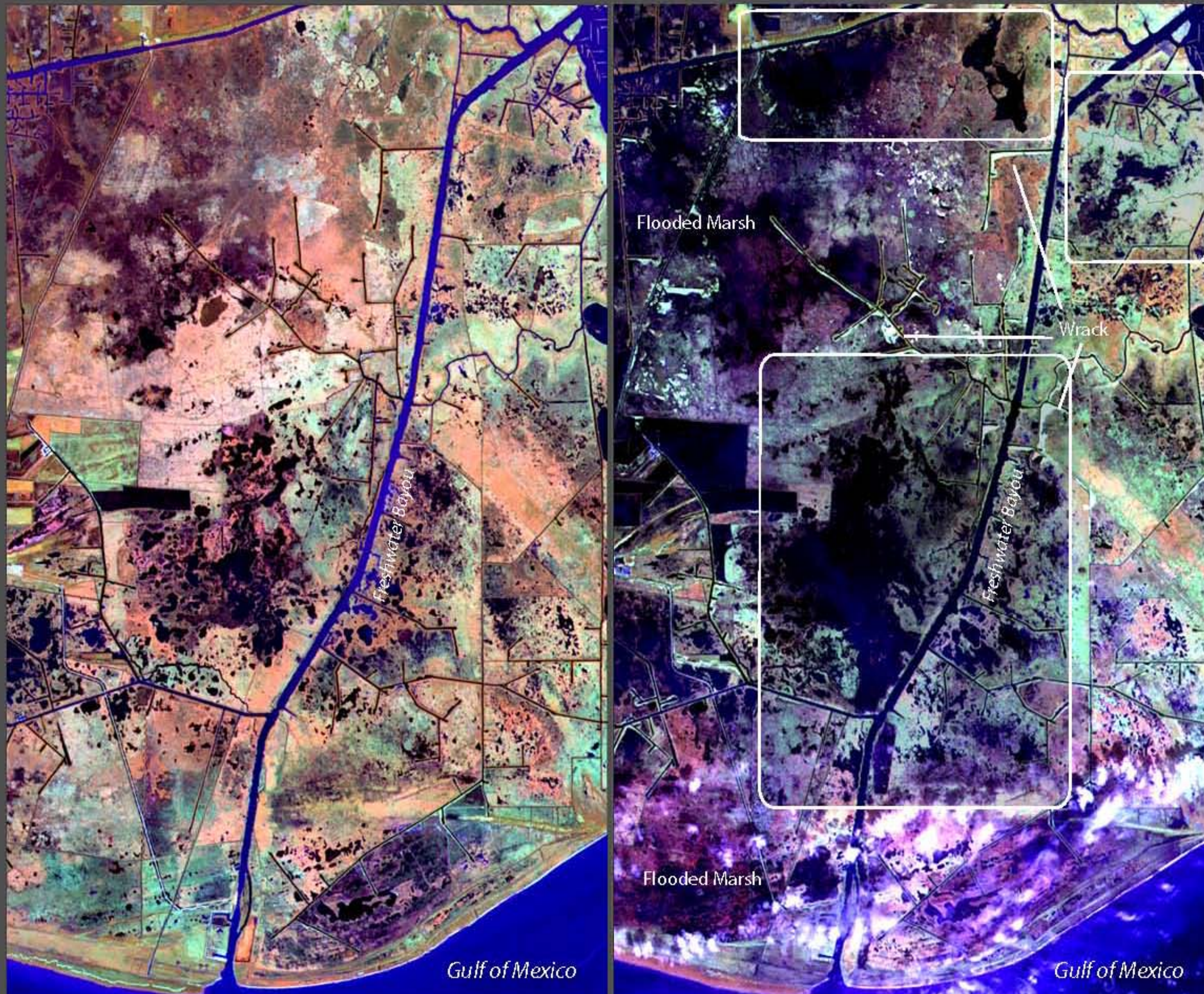
Landsat Thematic Mapper 5 Before and After Hurricane Rita Images for the Freshwater Bayou Area

October 13, 2002 - 10 Days After Hurricane Lili

September 30, 2005 - 6 Days After Hurricane Rita



Source: USGS NWRC
Landsat Thematic Mapper Satellite Imagery provided by EROS Data Center
Bands 4 (near-ir), 5 (mid-ir), and 3(visible red) displayed
Draft: Oct. 6, 2005

☐ Potential Shear/Ripped Marsh Area

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The Indian Ocean Tsunami – 2004

Maximum run-up exceeding 30 m in Banda Aceh and 10 m in several locations in Sri Lanka

Indian Ocean Tsunami Effects – Banda Aceh, 2005

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Pankarang Cape – Jan 13, 2003

Pankarang Cape – Dec 29, 2004

Katchall Island, India

July 10, 2004 December 28, 2004

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Approach

- Data Sources
- Projection Methods and Problems
- Animation Procedures

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Data Sources

- Global land cover, 30 arc-sec, 1 Gb file, USGS source
- Global elevation, Gtopo-30, 30-arc-sec, 2 Gb file, USGS source
- Global population, Landscan, 30 arc-sec, 1 Gb file, Oak Ridge National Laboratory source

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Projection of Data Sources

- All data originally in geographic coordinates (latitude and longitude)
- Projected to Mollweide for modeling and animation

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Projection Problems

- File size
- Run times
- Resampling
- Raster projection

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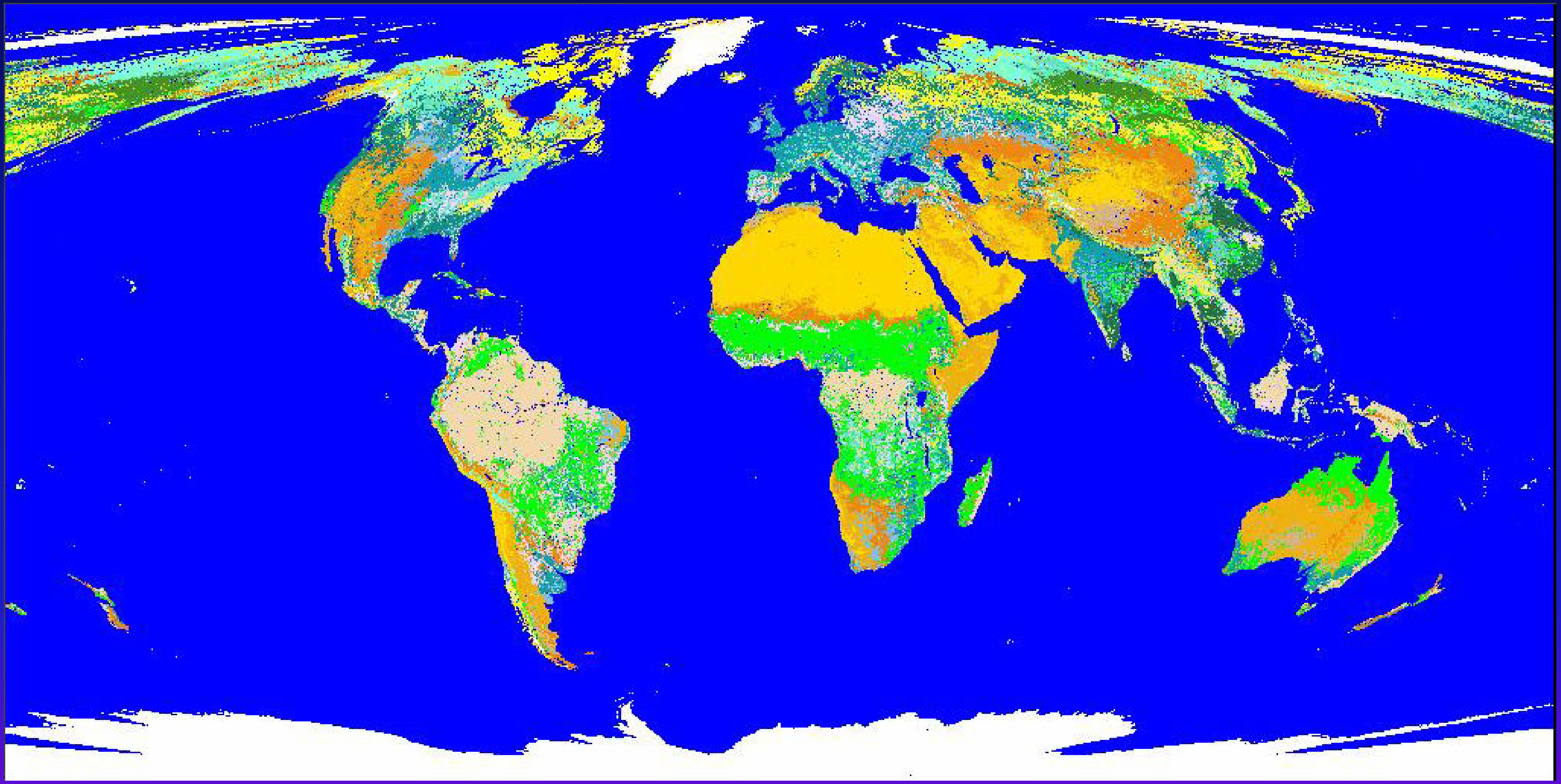
Projection Solutions

- USGS developed *mapimg* projections software
  - Handles global data, large file sizes
  - Programmed new resampler for categorical data (land cover)
    - Modal category, statistical selection, or user choice for output pixel value
  - Programmed new resampler for population counts
    - Additive resampler

The Wraparound Problem



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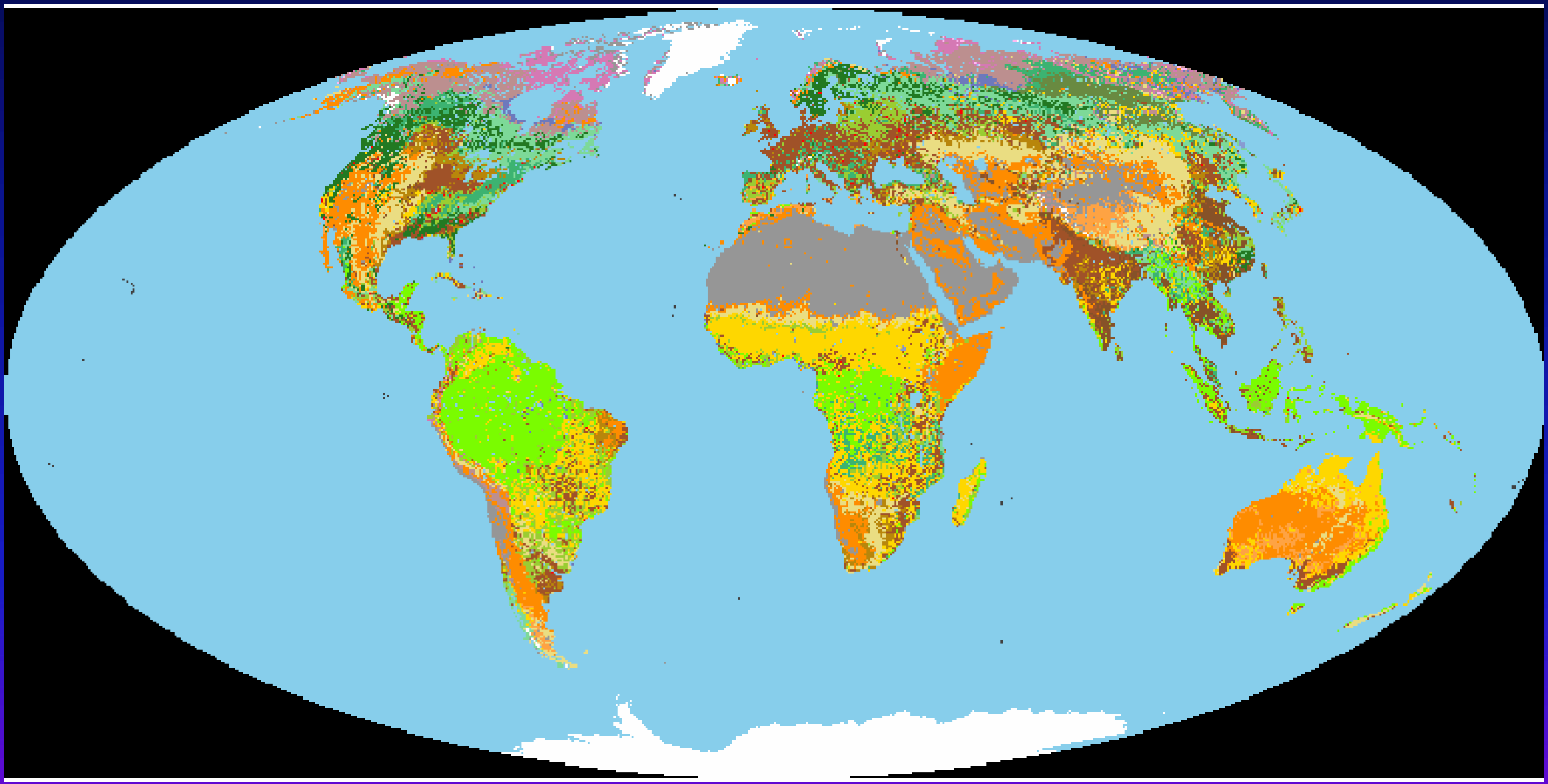
MapImg Output



Solves wraparound problem

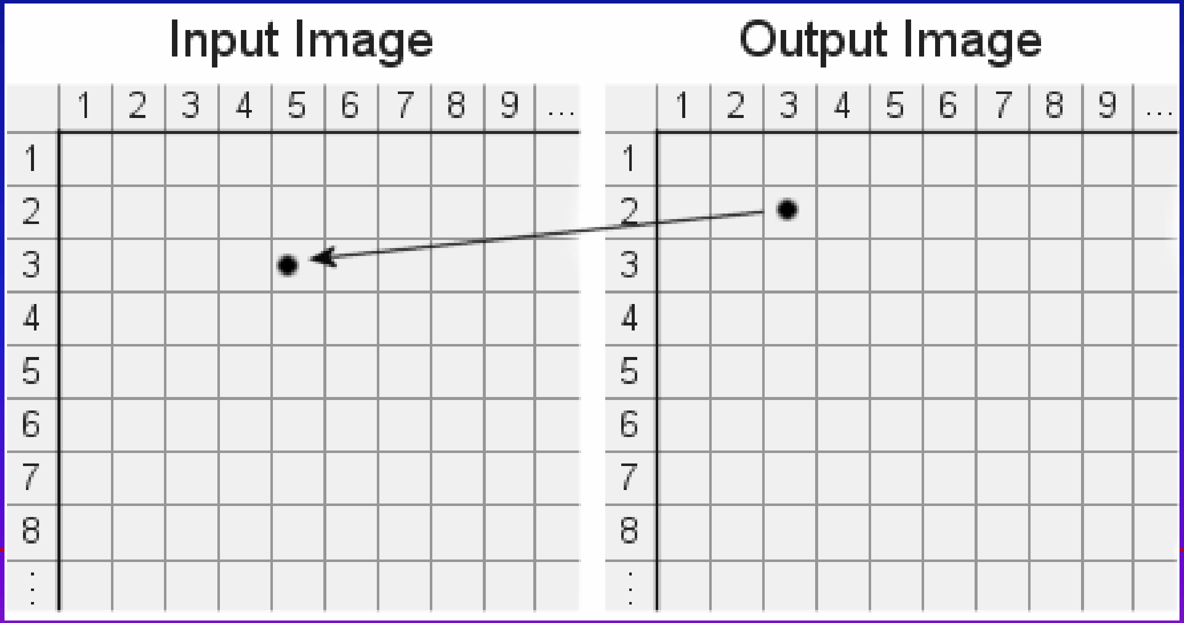
Downsampling (64 pixels to 1) and Reprojection with the Nearest Neighbor

Resampling

- Primary step in raster generalization, sometimes called down-sampling
- Geospatial data can suffer from great geometric distortions when being reprojected or transformed
- Errors associated with these distortions and scale changes affect resampling within the reprojection or transformation function, especially for categorical data, such as land cover, and population counts

Resampling – Nearest Neighbor Method without Generalization

- One point in the output image space maps to a corresponding point in the input image space (via the inverse mapping algorithm)



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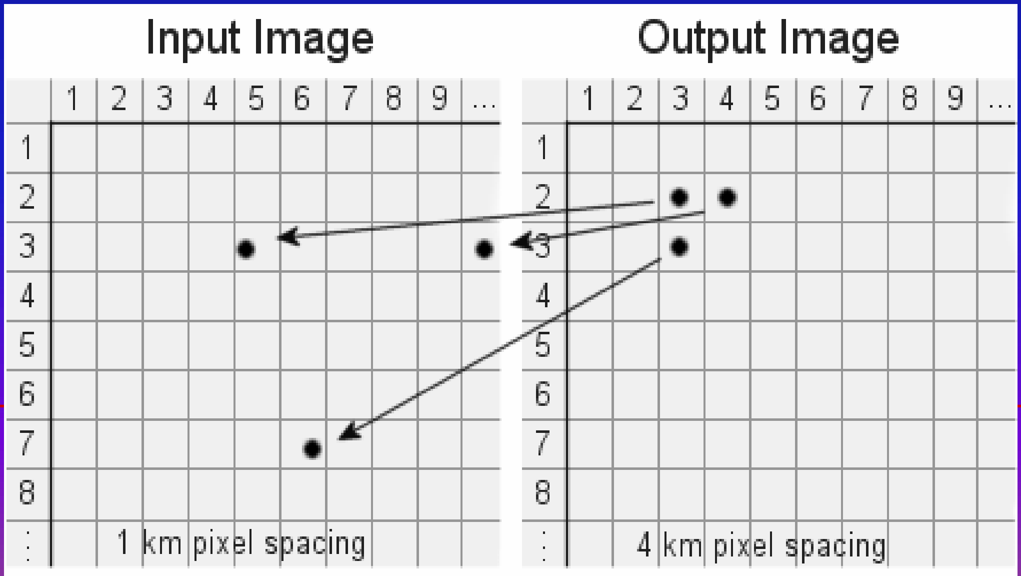
Resampling – Nearest Neighbor Method with Generalization (Down-sampling)

- **If the resolution of the output image is reduced (generalized or down-sampled), adjacent pixels in the output may fall more than one pixel away in the input (via the inverse mapping algorithm)**



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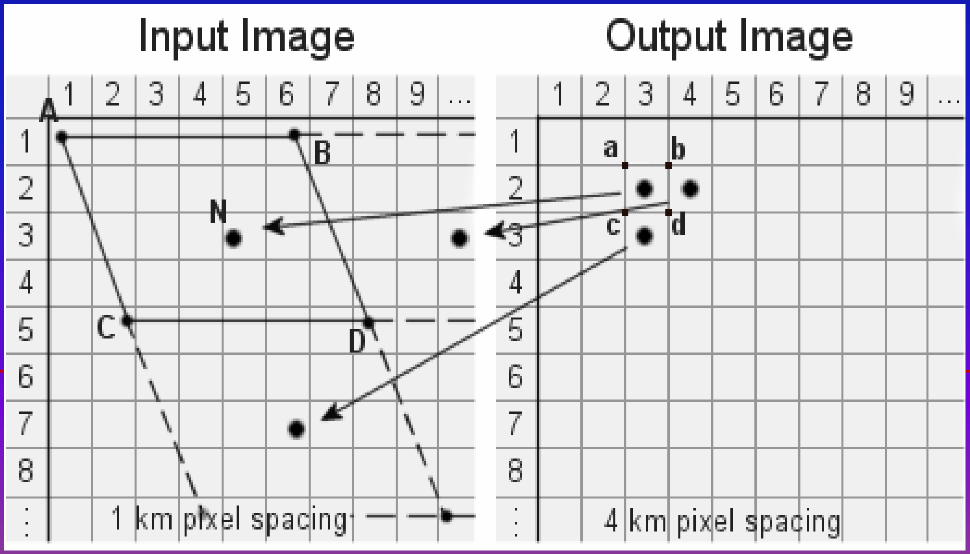
Categorical Resampling

- New resampling algorithm treats pixels as areas, not points, Steinwand (2003)
- Four corners of each pixel are mapped into the input space
- Many pixels involved
  - Apply simple statistical methods or user specification to determine output image pixels based on the area the pixel covers in the input image



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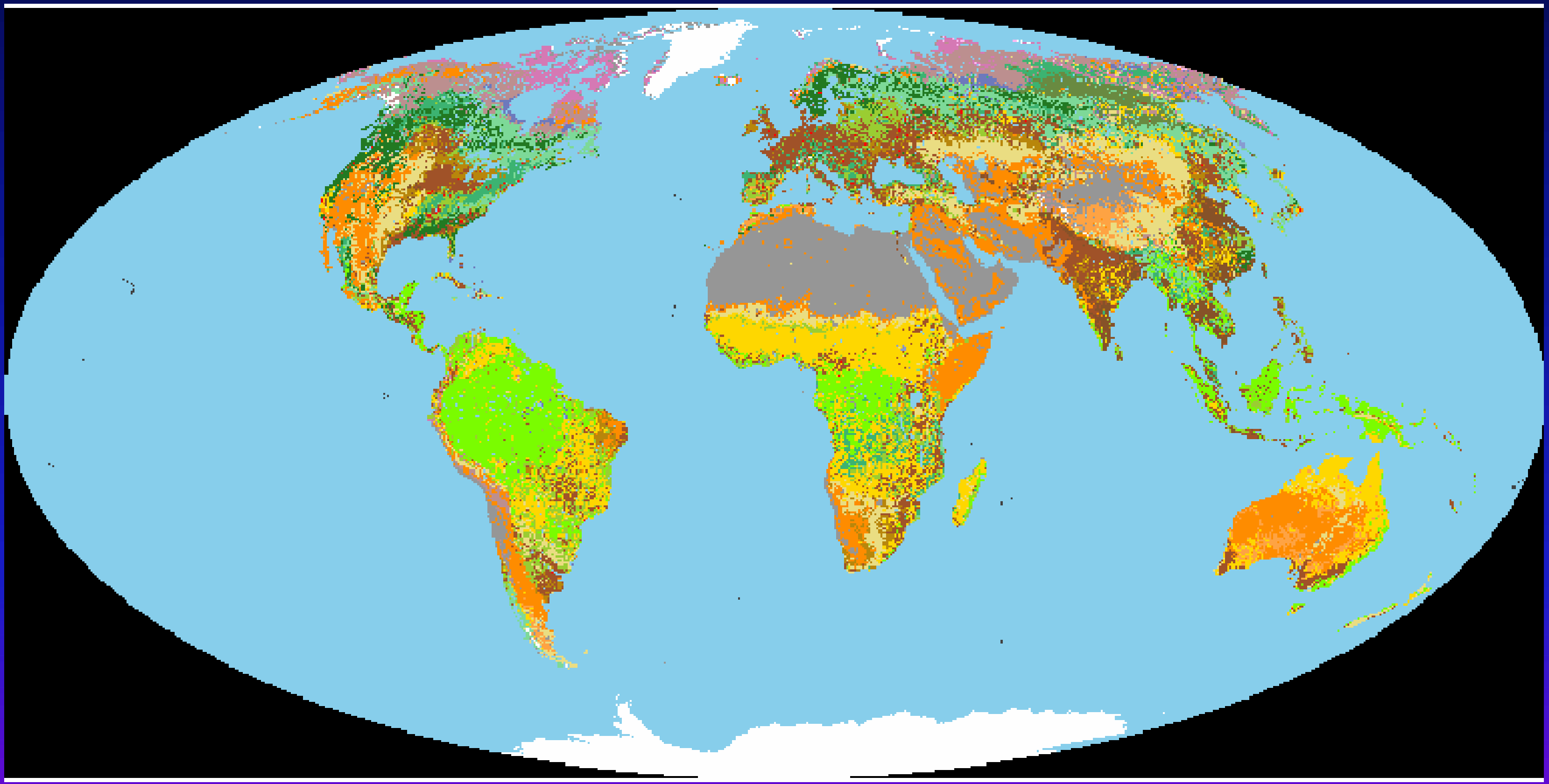
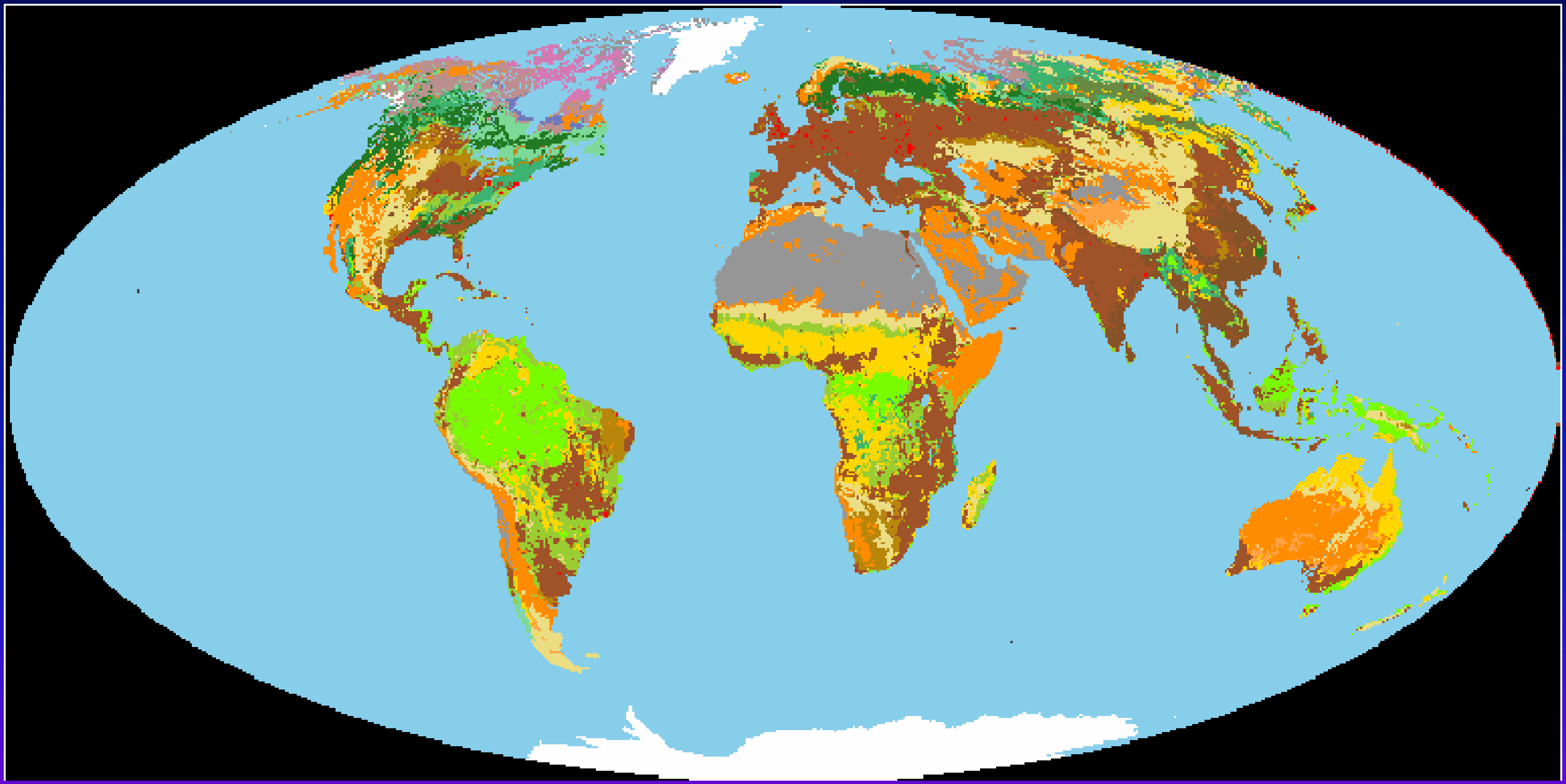
Extreme Downsampling and Reprojection with the Nearest Neighbor



Extreme Downsampling and Reprojection with the New Algorithm



Generalizing Population Counts

- Data are numbers of people per pixel
- Generalize four pixels to one
- Must add the four pixels together
- Not available in commercial software
- Developed in *mapimg*

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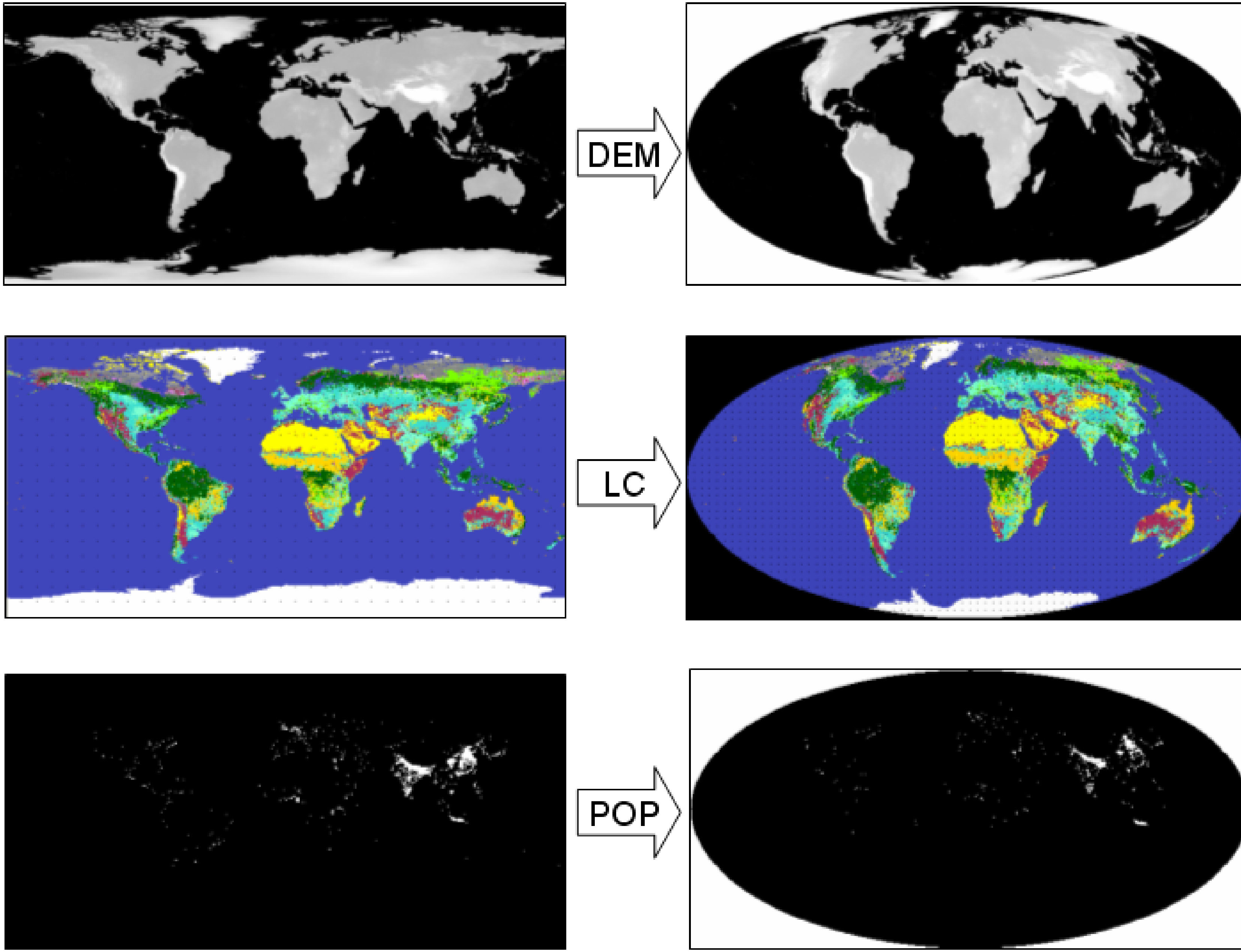
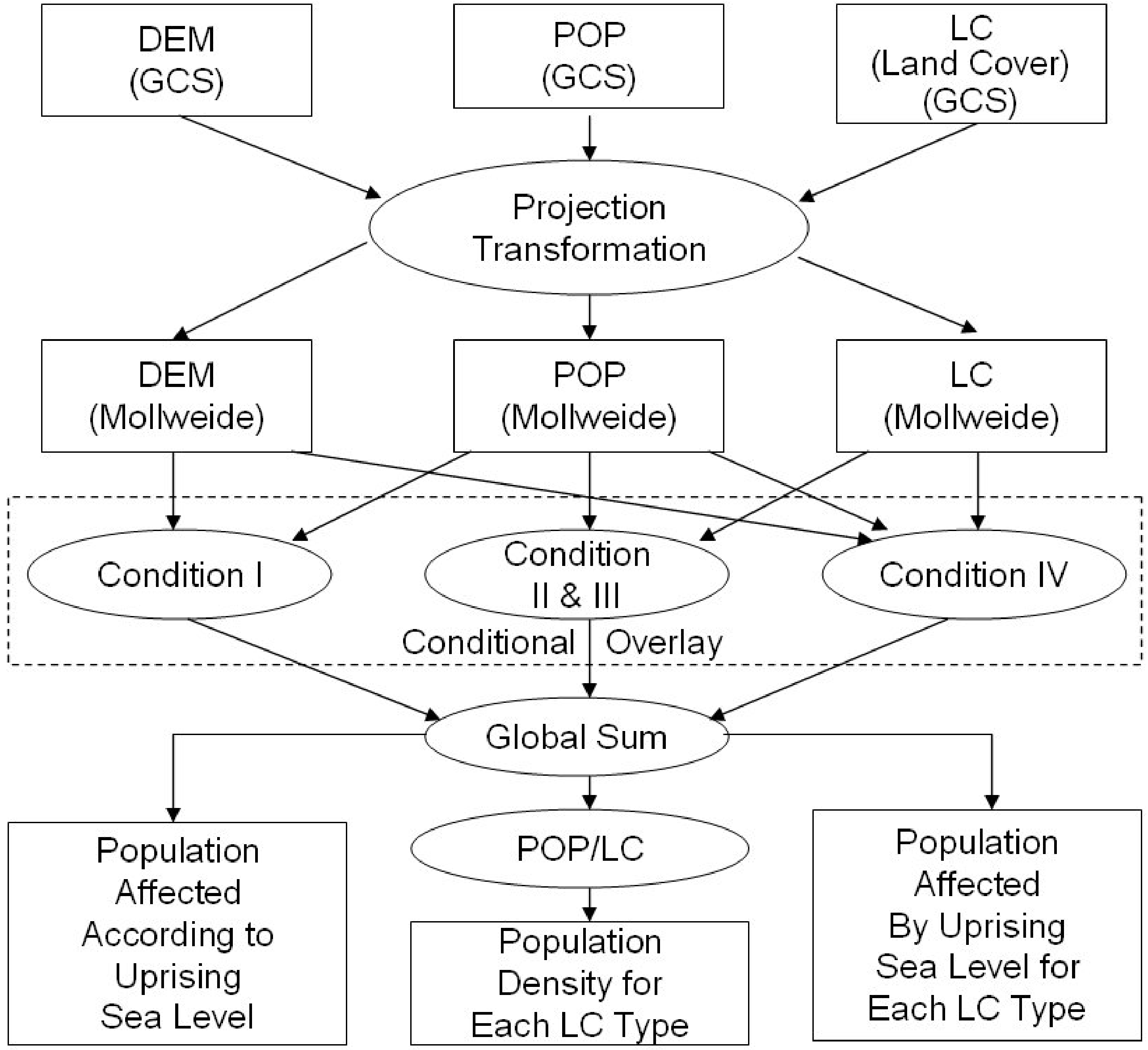
The Application to Global Data for Sea Level Rise Modeling


DEM
LC
POP



Condition I: If DEM≤5(10,20,30), then POP else 0

Condition II: If Land Cover = 1(..24), then POP else 0

Condition III: if Land Cover = 1(..24), then 1 else 0

Condition IV: if DEM≤5(10,20,30) and Land Cover = 1(..24), then POP else 0

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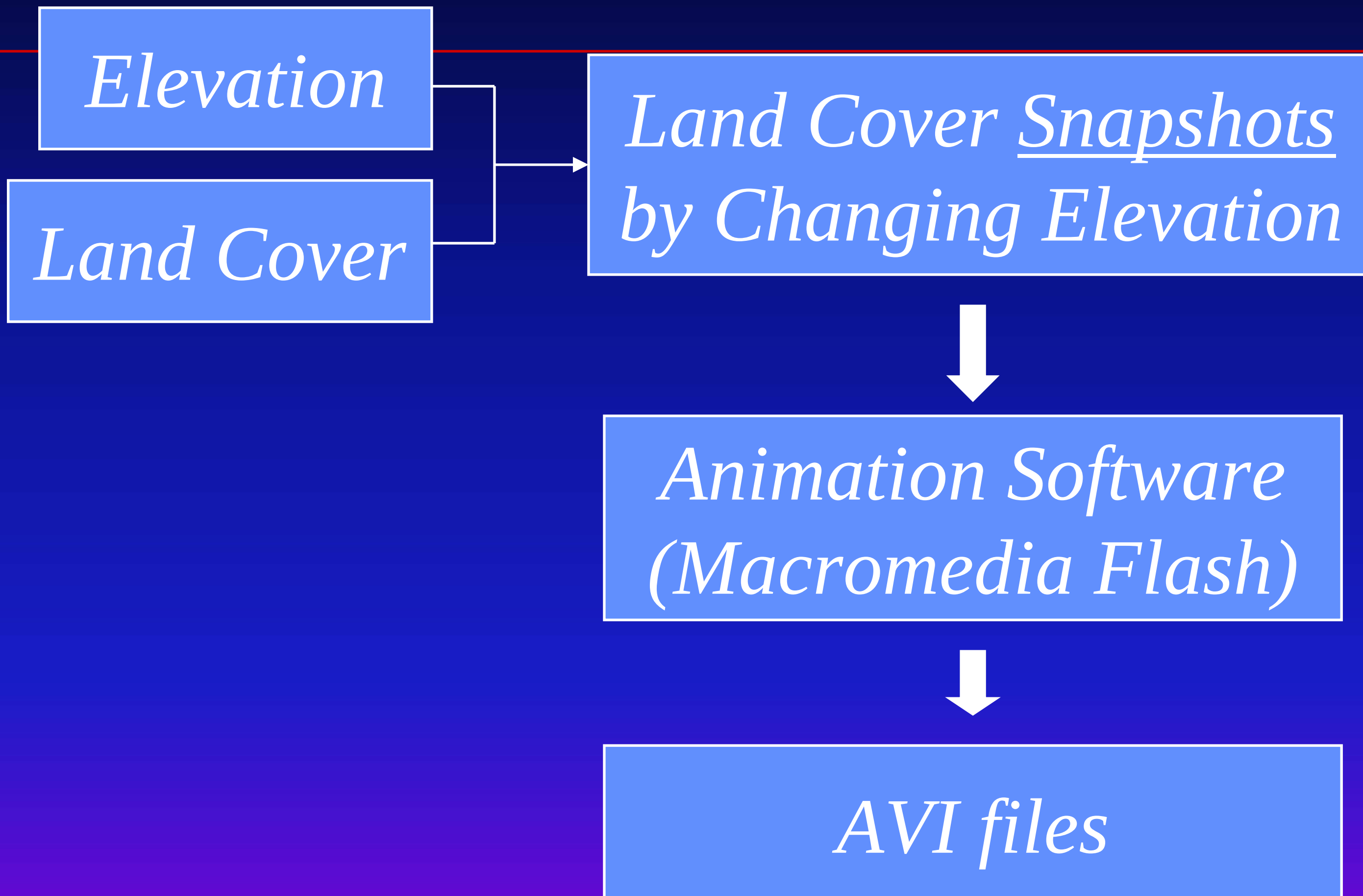
Animation Process



Results

Water Level Increase (m)	Population Affected (Net)	Area of Land Loss (km^2)
5	669,739,138	5,431,902
10	870,751,960 (201,012,822)	6,308,676
20	1,176,709,476 (305,957,516)	7,888,233
30	1,405,824,876 (229,115,400)	9,459,562

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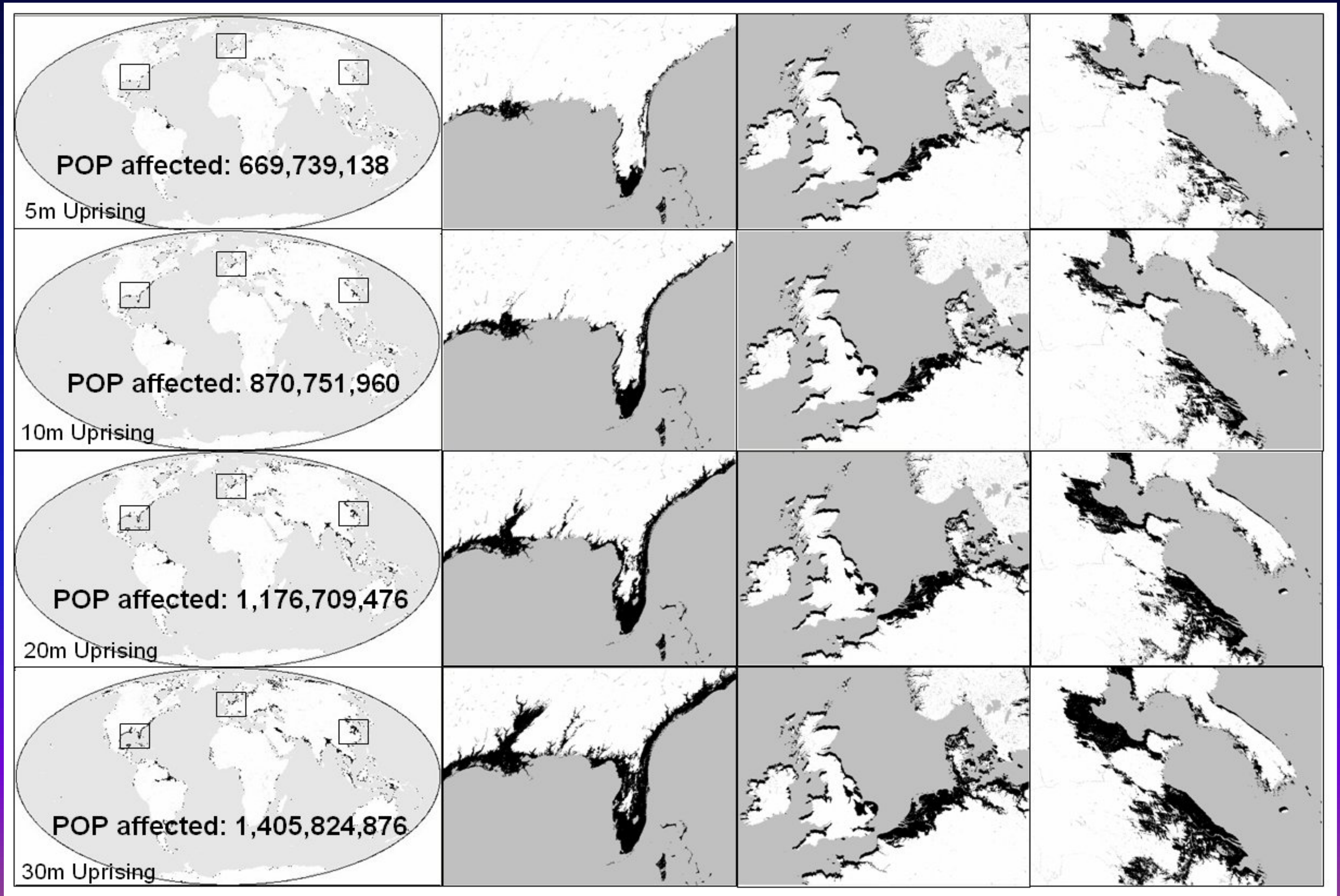
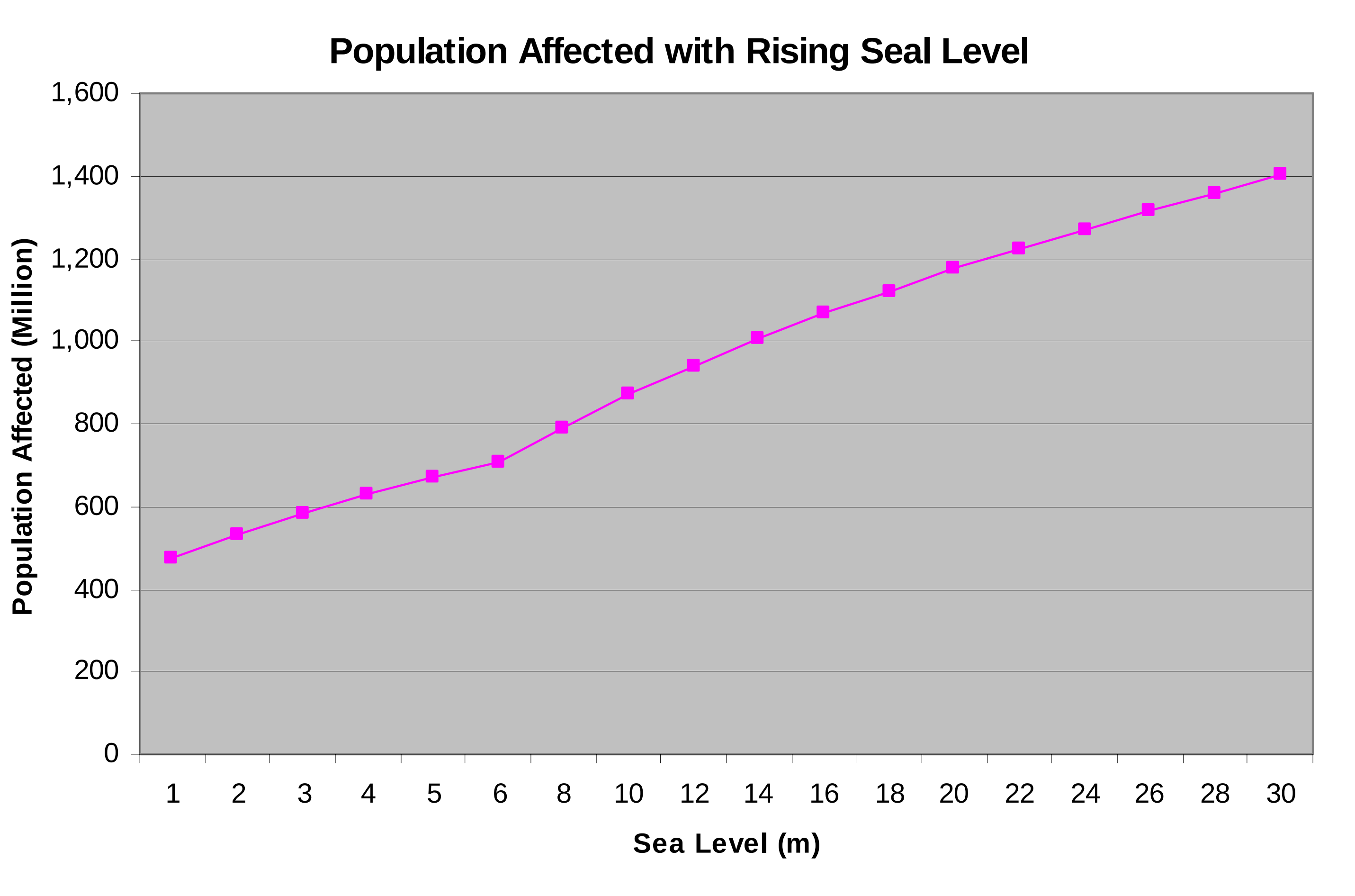
Results – Population affected and land loss



Results – Population effects



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Land Cover	POP Density (per km^2)	Total # of Population (%)	Population affected with Rising Sea Level (Meter)			
			5 (%)	10 (%)	20 (%)	30 (%)
Urban and Built-Up Land	3629.465	966,920,555 (15.5)	125,426,492 (18.7)	167,534,955 (19.2)	225,034,603 (19.1)	266,605,330 (19.0)
Irrigated Cropland and Pasture	392.719	1,285,065,525 (20.6)	146,650,929 (21.9)	231,800,008 (26.6)	353,447,741 (30.4)	439,098,227 (31.2)
Dryland Cropland and Pasture	121.907	1,480,209,129 (23.8)	90,514,229 (13.5)	117,463,463(13.5)	169,232,478 (14.4)	211,695,557 (15.1)
Cropland/Grassland Mosaic	90.342	394,546,228 (6.3)	18,977,528 (2.8)	28,429,804 (3.3)	46,827,725 (4.0)	62,004,537 (4.4)
Cropland/Woodland Mosaic	59.038	415,858,781 (6.7)	29,235,588 (4.4)	38,719,342 (4.4)	52,366,472 (4.5)	64,776,559 (4.6)
Savanna	26.962	414,375,468 (6.7)	11,853,796 (1.8)	15,467,596 (1.8)	21,710,314 (1.8)	26,744,460 (1.9)
Grassland	23.108	240,005,697 (3.9)	15,189,230 (2.3)	20,873,821 (2.4)	28,653,270 (2.4)	33,867,565 (2.4)
Wooded Wetland	21.817	341,190,481 (5.5)	22,577,955 (3.4)	31,003,493 (3.6)	42,853,389 (3.6)	50,464,119 (3.6)
Shrubland	19.383	18,005,767 (0.3)	5,088,510 (0.8)	5,871,408 (0.7)	7,046,719 (0.6)	7,603,461 (0.5)
Mixed Shrubland / Grassland	18.735	41,128,137 (0.7)	8,798,238 (1.3)	9,259,268 (1.1)	10,377,403 (0.9)	11,435,638 (0.8)
Total		6,228,997,089 (100)	669,739,138 (100)	870,751,960 (100)	1,176,709,476 (100)	1,405,824,876 (100)

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Animations

Animations are separate .avi files

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Conclusions

- Global sea level rise and storm surges potentially affect large numbers of people and various types of land cover
- Sea level rise can be modeled on a global scale with data at 30 arc-sec resolution
- Modeling requires specially designed projection and resampling software
  - Better categorical resampler for global land cover
  - Additive resampler for population counts
- Animation effectively portrays results and effects of potential sea level rise and storm surges

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